TWO-WAY MECHANO-ELECTRIC TRANSDUCER

The present invention relates to emitting and sensing acoustical or mechanical vibration, concurrently with receiving and transmitting electrical signals corresponding to a vibration state parameter. More in particular, the invention relates to a mechano-electrical transducer for emitting and sensing of vibration, and concurrent reception and transmission of at least one electrical signal that corresponds to the emitted or sensed vibration.

Transducers between electrical and mechanical energy (vibrations, force, acceleration) have many uses, and exist in various implementations. Often, two or three separate transducers are used e.g. in order to sense acceleration in three orthogonal directions, by having massive bodies, suspended in springing systems, move relative to respective reference frameworks.

From GB 2.055.018 and EP 118.329 are previously known transducers with a massive body suspended centrally in piezoelectric flexible "lamellas" or in piezoelectric filaments, for seismic and acoustical detection applications.

Related art can also be found in GB 2.166.022, which publication shows a transducer in the form of a loudspeaker, i.e. with transformation from electrical to acoustical signals, and using a massive body suspended centrally in a piezoelectric thin loudspeaker diaphragm that may be divided into several lamella-like areas by means of radial slits. Since it is common knowledge that a loudspeaker can also be utilized as a microphone, the last mentioned publication must be regarded to exhibit a bidirectional transducer. The point of the central body in the publication, is that it will be possible to lower the useful frequency range of the loudspeaker by adding such a centre mass.

The present invention aims at providing a bidirectional transducer that, better than previously known solutions, is able to operate with a directional effect and provide improved emission and detection, particularly in connection with echo measurements in biological tissue.

Hence, in accordance with the invention there is provided a mechanoelectric two-way transducer such as precisely defined in the appended claim 1. Preferable embodiments of the invention appear from the attached dependent claims.

In the following, the invention shall be illuminated in more detail by examining some exemplary embodiments, and in this connection it is also referred to the appended drawings, in which

Fig. 1 shows a first embodiment of the transducer in accordance with the invention, with transmit and receive activity in suspension sectors;

Fig. 2 shows an embodiment with an active centre body;

Figs. 3a and 3b show a first embodiment with a tautening structure for the centre body;

Figs. 4a and 4b show a second similar embodiment; and

Fig. 5 shows, schematically, an embodiment with signal phasing.

In Fig. 1 appears a first embodiment of the transducer 1 in accordance with the invention. A centre body 4 is suspended in an annular framework 2 in a plane suspension structure 3 in the form of a number of elastic and sector-shaped sheets 5, in this case eight such sectors 5.

In the embodiment shown in Fig. 1, the framework 2 is in its turn suspended in an outer frame 6 by means of an outer, elastic suspension structure in the form of elastic strings 7, however such an outer frame 6 with an outer suspension structure is not obligatory for the invention.

Signal wires 8 lead to and from the sectors 5, and possibly to and from the centre body 4, and a connector 9 is provided on the outer frame 6. The wires 8 are not shown in detail further inside the framework 2, but lead to and from each respective sector 5, and possibly to and from the centre body 4.

Every sector sheet 5 can be attached at the outer edge between two sections of ring 2, and at the inner "tip" between two hemispheres that constitute the centre body 4. The sector sheets 5 are for example made from PVDF (Polyvinylidene fluoride), which is a material having piezoelectric properties, and which material is able to convert an electrical input signal to a vibration that may propagate to a medium in front of (above) the transducer, for example body tissue, and the material is also able to convert incoming vibration waves hitting a sector (or several sectors), to electrical output signals. Every sector 5 is separately addressable with separate wires 8.

In this first embodiment, the centre body 4 is simply a solid body that, when the transducer is mounted as a front part of e.g. a handheld examination unit, will engage for example the skin surface of a patient, in such a manner that the central

part of the transducer will be pushed rearwardly. This causes the sectors 5 to be somewhat angled in relation to the unloaded position, and consequently a focusing effect is achieved, for example such as indicated in Fig. 1. It should also be noted that with an outer suspension structure 7 of elastic type, such as indicated in Fig. 1, some deflection down will occur there also. In an embodiment without such and outer structure, the deflection angle of the sectors will be more slanted.

Using a transducer of the type shown here, it will be possible to transmit vibrations with one or some sectors, at the same time as another sector, or some other sectors, are able to receive reflected vibrations, i.e. an echo.

Another advantage is the possibility to remove undesired signals, i.e. noise, using receive signals from different sectors in post-processing. In addition, it is also possible to connect a noise signal in opposite phase to the signal wires leading to e.g. one certain sector, in order to cancel the noise part of the receive signal of that sector. The noise signal that is coupled in, may for instance originate from a piezo-element arranged on the outer suspension structure 7, which structure receives an incoming noise signal, or from a separately arranged sensor.

In the embodiment appearing in Fig. 2, the centre body 4 is "active" also, i.e. the centre body itself contains piezo-elements 10 and 11, in this case a piezo-element 10 for transmitting vibrations, and a piezo-element 11 for receiving reflected vibrations. For the rest, the transducer is such as stated in connection with Fig. 1. The signal wires to the piezo-elements of the centre body are not shown in Fig. 2, but they follow paths on the sectors 5 up to the centre body 4.

In the shown embodiment, the piezo-elements 10 and 11 are cast-in "half-moons" of piezo-material. The manner of use of such an embodiment as discussed here, will for example be that the piezo-element 10 of the centre body transmits high frequency vibrations, generally in the range 5-10 MHz (however not limited to this range), in order to make an echo Doppler investigation. Reflected vibrations are picked up by means of element 11.

Simultaneously with the echo Doppler investigation with centre body 4, the sectors 5, or some of them, can be used for ordinary auscultation, i.e. for pure listening to acoustical vibrations from a body.

In Figs. 3a and 3b appear an embodiment of the transducer in accordance with the invention, in which embodiment it is possible to change and keep a check on the slant angle of the sectors (compare the slant angle mentioned above, obtai-

ned by pushing the centre body 4 against a surface). This is achieved by designing the centre body 4 with an extended rear piece 14 that is held by a sleeve 15 in such manner that this sleeve can rotate around a lower (not shown) ball or enlargement on the rear piece 14, so that the rear piece (and consequently the centre body) can be pulled down when the sleeve 15 travels down while rotating. Such a rotating travel in a down direction is caused by rotating head 13 so that a threaded section inside part 16, held by a number of stays 12, cooperates with threads on bolt 17, to provide a vertical travel. In this manner it is possible to regulate the slant angle and the tensioning of the sectors 5.

As indicated in Figs. 3a, b, the stays 12 are attached to the ring 2, so the tensioning will influence only the main part of the transducer with sectors 5. But in Figs. 4a and 4b appears a variant in which the stays 12 are attached to the outer ring 6. This means that also the outer suspension structure will be tensioned and set in a slanting angle by means of the adjustment system 12-17.

The curved shape of the stays 12 is practical, however not mandatory.

It can be added that the transducer embodiments shown in Figs. 3 and 4, are intended to operate along the same principles as mentioned regarding the embodiments of Fig. 1 and 2.

In Fig. 5 appears, schematically, an embodiment in which it is possible to provide, by controlling in a detailed manner the signals applied to the respective piezoelectric sectors 5, further enhanced directional control of an emitted mechanical oscillatory wave. One will then use a principle that is known from antenna technology, for example within the art of cellular telephony, wherein antennas consisting of a plurality of antenna elements, are "fired" with small mutual delays or phase shifts, in such a manner that constructive interference is achieved in a desired direction outward from the total antenna. (This principle is also used when receiving/listening, i.e. "listening windows" are opened in attached receiver electronics, in "phased succession", and part signals are added so as to effectively listen in certain directions.)

Consequently, directional and phased emission of mechanical vibration waves are provided by making a control unit 21 supply phase shifted (and possibly intensity adjusted) signals to the sectors 5 via the multiwire cable 20 and the multiconnectors 19 and 9 and wires 8, to contact points 18 on every sector, to provide phase-controlled signals for the sectors. (Further detailed control can possibly be

achieved by additional radial sectioning of the active piezoelectric sector areas, and with separate signal supply thereto.) The signal wires 8 and contact points 18 are only shown in a schematical manner. For example, all wires 8 have not been shown to be leading all the way to the connector 9, but of course this is the intention. In Fig. 5, the transducer is, for simplicity, shown in an embodiment without an outer frame, but such an outer frame 6 as in the other figures can of course be used also in the "phased" embodiment.

Reception/listening can of course also be done in accordance with the same phasing principle. A computer unit in the control unit 21 handles the signal phasing in emission as well as in reception, in accordance with programmed algorithms.